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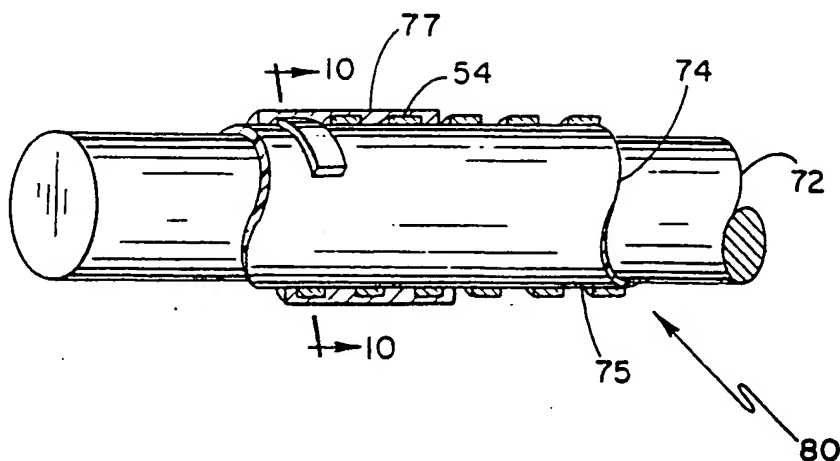
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(54) Title: KINK RESISTANT TUBING APPARATUS



(57) Abstract

A kink resistant tubing (10, 20, 30, 40, 50, 60, 70, 80, 90) used in intravenous catheters. The kink resistant tube is composed of a mandrel (72) with a thin coating of encapsulating material (74) upon which a coil (54) is wrapped. The coil wrap encapsulating material is then covered with encapsulating material (74) to form a kink resistant reinforced tubing (10, 20, 30, 40, 50, 60, 70, 80, 90). The mandrel (72) is extracted from the tubing (10, 20, 30, 40, 50, 60, 70, 80, 90). The tubing (10, 20, 30, 40, 50, 60, 70, 80, 90) can be used in medical applications or where a thin, non-collapsible small strong tubing is needed.

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KINK RESISTANT TUBING APPARATUS

This invention relates to a kink resistant tubing and more particularly to a kink resistant tubing made from a thin layer of encapsulating material and a reinforcing coil.

BACKGROUND OF THE INVENTION

Kink resistant tubing finds application as a material to construct medical catheters for infants, children and adults. The main application of catheters is for central venous access. Central venous access can be used for the administration of drugs, fluids or the monitoring of pressures. Administration of drugs implies the use of intravenous fluids, continuous drips or boluses of drugs.

There are different routes of placing catheters in infants and children. The first route of central access in a neonate is an umbilical artery catheter or venous catheter. Catheters are placed into umbilical artery or vein, in the remaining stump of the umbilical cord in the infant. Such a catheter can be used for monitoring blood pressure, central venous pressure, administering life sustaining drugs, or delivering IV fluids. Other routes of catheterization include the wrist or a radial artery. Usually drugs are not given by this route. In older children, after the neonatal period, the femoral artery and vein can be used, or the right internal jugular veins. Another route less commonly used in children, but nonetheless very useful for treating adults and teenagers, is the subclavian vein for central monitoring.

In addition to routine monitoring and drug administration, these catheters may also be employed in a procedure known as cardiac catheterization. This is a procedure by which pressures of the heart can be monitored as well as blood withdrawal from the catheter to measure oxygen tension and Ph in the

chambers of the heart. Oxygen tension is the oxygen saturation and the partial pressure of oxygen in blood samples in the various chambers of the heart. These catheters can be advanced into the heart through
5 either a femoral route, which is the most common router, or through a vein in the arm known as the brachiocephalic.

Another application for catheters is blood withdrawal. Catheters placed in arteries or central
10 veins are convenient routes for blood withdrawal.

Prior art catheters for central venous access and cardiac catheterization consist of tubes made of a plastic tubing of a pliable plastic. The plastics come in different types that have various degrees of
15 pliability depending upon the temperature. These catheters are usually fairly stiff at room temperature but become very soft as they are exposed to body temperature.

Plastic catheters of the prior art have many
20 disadvantages. As noted above, they are fabricated from plastics which often soften when inserted into a body. As a result, such catheters become more difficult to manipulate. Such prior art catheters have a tendency to kink and buckle when they become
25 pliable while implanted in blood vessels. The mechanism of failure includes kinking which may occur, for example, when the catheter butts up against the wall of a vessel. Such catheters may also kink by folding back on itself while being advanced into a
30 vessel. When a catheter kinks it is no longer able to transport drugs or IV fluids into the vessel. Kinking also effects the withdrawal of backblood from the catheter. Methods of remedying an obstructed catheter can consist of flushing the catheter with a bit of
35 high pressure fluid to try to remove the kink. If the kinking is severe enough, the catheter must be removed

and replaced with a new one. Unfortunately, life-threatening conditions can occur from a kinked catheter, as, for example, in the event that the obstruction of flow of a life sustaining drug to the patient is obstructed by kinking.

Long-term catheters such as the Hickman and Broviac catheters are implantable catheters that are implanted under the skin into central veins, usually through a subclavian route or an internal jugular route, and occasionally through a femoral route. These catheters are also implanted in an area near the neck where they can be kept clean. These catheters are implanted on a permanent basis. They are usually used for patients with chronic illnesses, such as, for example, in the case of children who receive chemotherapy.

Use of catheters in adults parallels many of the pediatric uses discussed above. Catheters can be placed for temporary and permanent use in jugular and subclavian vessels. Catheters can also be made for use in cardiac catheterization. Small bore catheters such as those provided by the instant invention enjoy a distinct advantage over larger bore catheters because they can form certain shapes for use in areas such as cardiac coronary catheterization.

It is therefore a motivation of the invention to provide a kink resistant tubing that can be used in medicine and allied fields. It is also a motive of the invention to provide a catheter that avoids the potentially hazardous problem of collapsing within a body vessel.

SUMMARY OF THE INVENTION

A kink resistant tubing is provided that is made of a thin wall polymer and metal or fiber composite. The kink resistant tubing apparatus of the invention exhibits superior kink resistance when subjected to

severe bending stress. The kink resistant tubing apparatus of the invention also has a thin wall thicknesses in comparison to the prior art. The kink resistant tubing is made of an encapsulated reinforcing coil structured around a mandrel.

It is an object of the invention to provide a thin wall polymer encapsulated kink resistant tubing.

It is another object of the invention to provide a thin wall tubing that exhibits superior kink resistance when subjected to severe bending.

It is yet another object of the invention to provide a thin wall kink resistant tubing that provides superior performance over existing tubing designs used in medical products for interventional catheters.

It is yet another object of the invention to provide an improved kink resistant tubing apparatus able to withstand severe radii of curvature without kinking or buckling.

It is yet another object of the invention to provide a kink resistant tubing apparatus that exhibits extremely reduced wall thicknesses in comparison to the prior art for use in catheter tubing.

It is yet another advantage of the invention to provide a very small gauge catheter.

It is a further object of the invention to provide an improved catheter for use in the small vessels of infants and children.

Other objects, features and advantages of the present invention will become apparent to those skilled in the art through the description of the preferred embodiment, claims and drawings herein where like numerals refer to like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A shows an idealized schematic of the

kink resistant tubing apparatus of the invention.

Figure 1B shows the kink resistant apparatus of the invention in an idealized cross-sectional schematic.

5 Figure 2A shows a schematic of one example of the kink resistant tubing apparatus of the invention

10 Figure 2B shows one example of the kink resistant tubing apparatus of the invention in a cross section shown using a thin wall encapsulation method with a cut away of reinforcing coil supports.

Figure 3 shows a schematic of one example of kink resistant tubing as provided by the invention showing a plurality of reinforcing coils.

15 Figure 4 shows one example of the kink resistant tubing of the invention with a cross-sectional view of the thin wall incorporating a composite fiber reinforcement.

20 Figure 5 shows an isometric isolation view of a supporting coil as employed in one embodiment of the invention.

Figure 6 shows an isometric view of the thin wall kink resistant tubing apparatus of the invention incorporating a reinforcing coil.

25 Figure 7 shows the first step of manufacturing the apparatus of the invention with a mandrel coated with a thin layer of encapsulating material with the encapsulating material cut away. Figure 8 shows a cross-section of a mandrel as employed by the method of the invention with a thin layer of encapsulating material.

30 Figure 9 shows a mandrel and a thin layer of encapsulating material as employed by the method of the invention with a cut away of the coil wound around the thin layer of encapsulating material.

35 Figure 10 shows a kink resistant tubing cross-sectional diagram with a reinforcing coil wrapped

around the thin encapsulating layer around the mandrel as employed by one method of the invention.

Figure 11 shows the apparatus of the invention in its final constructed state on the mandrel.

5 Figure 12 shows a cross-section of the mandrel with the apparatus of the invention in final constructed state.

10 Figure 13 shows the method of removing the kink resistant tubing apparatus of the invention from a mandrel.

Figure 14 shows the kink resistant tubing apparatus being removed from the mandrel in a cross sectional view.

DESCRIPTION OF THE PREFERRED EMBODIMENT

15 Now referring to Figure 1A which shows a isometric view of one embodiment of the kink resistant tube of the invention. The kink resistant tube 10 is comprised of an ideally substantially circular inside wall 18 and an outside wall 16, which is ideally
20 substantially perfectly smooth. Tube 10 is composed of encapsulating material 12 and an encapsulated coil 14 shown in Figure 1B.

Now referring to Figure 1B which shows a cross-sectional diagram of the tubing apparatus of the
25 invention shown in Figure 1A. Figure 1B shows a thin walled kink resistant tube 10 constructed of an encapsulating material 12 containing a spiral wound reinforcing coil 14. Figure 1B shows a cross-section of the tube 10 showing substantially half of the tube
30 10. In one embodiment of Figure 1B the outside wall 16 is substantially smooth and parallel to the inner wall 18.

Now referring to Figure 2A which shows one
embodiment of the apparatus of the invention which is
35 manufactured with the kink resistant tubing construction method of applicant's copending

application KINK RESISTANT TUBING METHOD, Attorney Docket Number 1511 filed on the same date as the instant application. The kink resistant tubing 20 has a ribbed surface 26 and walls 22. The walls 22 contain a reinforcing material 24 as shown in Figure 2B. The ribbed surface 26 comprises a plurality of ribs 25. The ribbed surface 26 closely follows the contours of the reinforcing material 24 embedded within the walls 22 of the kink resistant tubing 20. The kink resistant tubing 20 has a substantially smooth inside wall 28 through which various fluids may pass. Each of the plurality of ribs 25 is comprised of an encapsulating material around embedded reinforcing members 24.

Now referring to Figure 2B which shows the kink resistant tubing of Figure 2A in cross-section. The reinforcing members 24 are embedded in a thin encapsulating material 22. The reinforcing members 24 in the example embodiment of Figure 2B are advantageously comprised of a spiral wound rectangular cross-section metallic spring which is wound around and within the encapsulating material 22. Figure 2B also shows the plurality of ribs 25 of the outer surface 26 of the kink resistant tubing 20.

The strength and versatility of the kink resistant tube 20 is illustrated by the cross-section in Figure 2B. The tubing is better able to withstand the hoop stresses of any internal pressure indicated by pressure arrows P on the tube wall 28. The hoop stress in the tube encapsulating material 22 is transferred to the reinforcing members 24. Those skilled in the art will recognize that the reinforcing members could either be a spiral wound spring-like structure or could be separate, individual rings independent of each other. The quality of the reinforcing material is advantageously such that the

radial hoop stress is substantially adsorbed continuously radially around the tube by the reinforcing member.

Now referring to Figure 3 which shows the kink resistant tubing apparatus of the invention in a two-dimensional projection with the reinforcing members 34 in a top down view. Figure 3 also shows the outside surfaces 26 of the kink resistant tubing 30. Encapsulating material 22 comprises the material between the reinforcing members 34. The reinforcing members 34 can alternately be comprised of coiled wire made of various sizes and shapes. The encapsulating material 32 is used for the total encapsulation of the reinforcing coil 34, as the elastomeric medium and for providing a smooth internal and external surface.

The materials of choice for the kink resistant tubing 30 are elastomers such as polyurethane or silicone rubber. Different materials will result in various levels of flexibility and kink resistance. Those skilled in the art will also recognize that when increased torque is applied to the kink resistant tubing 30 additional reinforcement in the form of multi-wire braiding, multi-filer windings and other metallic or nonmetallic reinforcement may be used.

After extensive testing in the laboratory certain materials and material types had shown particular suitability to use in the kink resistant tubing encapsulating material. Table A lists these materials and tradenames as well as which manufacturers they are available from.

TABLE A

<u>MATERIALS</u>	<u>MANUFACTURES (TRADE NAMES)</u>
(A) polyesterurethane:	B.F. Goodrich (Estane) DuPont (Hytrel)
(B) polyetherurethane:	Dow (Pellathane) B.F. Goodrich (Estane)

- (C) aliphatic polyurethane: Thermedics (Tecoflex)
- (D) polyimide: DuPont (Pyraline)
- (E) polyetherimide: General Electric (Utem)
- (F) polycarbonate: Mobay (Apec)
- 5 (G) polysiloxane: Dow Corning (Silastic)
Dow Corning (MDX-4159)
- (H) hydrophilic polyurethane: Grace Co. (Hypol)
- (I) polyvinyls:
- (J) Latex:
- 10 (K) hydroxy-ethyl methacrylate:
- (L) blends of the above materials:
- (M) most any other elastomer that can be carried in solvent:

The above-listed materials when used alone or as
15 components to a blend of materials displayed the best
performance in tubing manufactured by Navarre
Laboratories Ltd. of Minnesota. The subsequent
products produced with these materials allow for a
range of performance characteristics. Some of the
20 blends of materials are discussed hereinbelow offered
specific performance advantages.

Those skilled in the art will appreciate that the
materials described above have application in the
manufacture of medical devices including tubing in the
25 prior art. When manufactured into prior art devices
the listed materials have displayed superior
performance characteristics. The materials have found
uses in guidewire coating, Laparotomy/Cholecystectomy
devices, vascular probes, peripheral and coronary
30 catheters, vascular access catheters, and ophthalmic
devices.

In the present kink resistant tubing apparatus of

the invention these materials have been successfully used for the first time to manufacture both the thin walled inner tube and the outer encapsulating tube. These materials have been prepared with a solvent system material manufacturing process according to the following proportions listed in Table B. The materials listed herein are by way of illustration and not by way of limitation. Similar materials known to those skilled in the art having equivalent properties may also be used.

TABLE B

15	(A) urethanes:	solids:	6% to 14%
		solvents:	THF/DMF 85/15 (THF - Tetrahydrofuran, DMF - Dimethylformamide)
		viscosity:	10-100 centiStokes
20	(B) polyimide:	solids:	20% - 45%
		solvents:	N-Methylpyrrolidone
		viscosity:	80-1000 centiStokes
	(C) polyetherimide	solids:	8% to 12%
		solvents:	methylene chloride
		viscosity:	40-100 centiStokes
25	(D) polycarbonate:	solids:	6% to 12%
		solvents:	THF/DMF 85/15
		viscosity:	10-60 centiStokes
30	(E) polysiloxane:	solids:	30% - 60%
		solvents:	111-trichloroethane
		viscosity:	100-450 centiStokes
	(F) hydrophilic polyurethane:	solids:	.1% - 95%
		solvents:	water
		viscosity:	not applicable

35 Having described the apparatus of the invention, the method by which the apparatus is fabricated will now be described in detail. The preparation of the kink resistant encapsulating materials is accomplished by following a series of steps. The preparation

process is similar for all materials. The solid or liquid material is first weighed. The solvent is then prepared. The solvent is added to the solid or liquid material in the appropriate amount to make the desired
5 percent solids. Stirring is necessary to completely solvate plastic materials. Once the plastic is completely in solution the material is ready for use in coating applications for the kink resistant tubing of the invention.

10 The encapsulating material 22 is configured to substantially cover the reinforcing members 34. Those skilled in the art will recognize that if a reinforcing coil is found that has excellent bio-compatibility qualities that the tubing coil may not
15 need encapsulation.

Various different types of encapsulating materials can be used to manufacture the kink resistant tubing encapsulating material. Those include, but are not limited to, polyurethane,
20 silicone rubber, polyurethane/polycarbonate blends, polyurethane/silicone blends, polyvinylchloride, polyimide and latex.

Now referring to Figure 4 which shows another example of the kink resistant tubing apparatus of the
25 invention in an enlarged cross-section diagram. The kink resistant tubing 40 has the encapsulating material 42 which in this example embodiment of the invention is advantageously substantially comprised of silicone rubber. The reinforcing members 44 comprise
30 a composite wound fiber 44 which comprise the composite tubing's 40 coiled reinforcement member. The outer surface 26 of the composite tube 40 is formed by the encapsulating material 42.

Now referring to Figure 5 which shows a schematic
35 isometric drawing of an example of a reinforcing coil 50. The reinforcing coil 50 in the kink resistant

tubing apparatus of the invention provides radial strength and hoop strength. The reinforcing coil 50 helps retain the circularity of the tubing 10 and thereby avoids buckling and kinking of the tubing 10.

5 The reinforcing coil 50 also provides a crush-resistance to the reinforcing coil. The reinforcing coil 50 comprises a wire or fiber 54 which may have various cross-sectional shapes, such as, for example, rectangular, circular, or elliptical. Those skilled
10 in the art will recognize that the cross-sectional shapes will effect the load bearing characteristics and strength characteristics of the reinforcing coil 50. In the example of Figure 5 the cross-section 52 is rectangular with a flat face 56 and flat body 58.

15 Various different reinforcing coil 50 materials may be used. Further, the reinforcing coil dimensions can vary as well as the reinforcing coil 50 pitch and diameter. Listed below in Table C are some of the alternative coil 50 design parameters that can be
20 used.

TABLE C

Coil Wire Size:	0.001-0.015
Coil Wire Material:	metals; stainless steel, MP35, NiTi, Tungsten, 25 Platinum, kevalar, nylon, polyester, acrylic
Coil Pitch:	1-5 times maximum coil wire dimension
Coil Diameter:	0.010-0.375 inches

30 Referring now to Figure 6, an isometric view of one embodiment of the kink resistant tubing 60 of the invention is shown using a wire or fiber 54. The kink resistant tube 60 construction method comprises four major steps listed in Table D. These four major
35 process steps are described in detail below with

reference to Figures 7-14.

TABLE D

1. Mandrel Coating
2. Coil Wrapping of Mandrel Substrate
- 5 3. Over coating the coiled assembly
4. Mandrel Extraction

Now referring to Figure 7 which shows a mandrel 72 with a thin film encapsulating material 74. In Figure 7 the encapsulating material 74 is shown in a cut away view. The mandrel 72 provides the internal dimensions of the kink resistant tubing. The mandrel may be advantageously constructed from a fluoropolymer such as PTFE or FEP, polyethylene, nylon, or possibly a ductile metal such as silver. The mandrel 72 may be tubular or solid and may advantageously diametrically reduced upon the application of sufficient stretching force. If a tubing is used for the mandrel 72, a support rod, usually metallic, can be used to provide increased straightness and stiffness.

The mandrel is coated with a thin layer or layers of the encapsulating material 74 in solution form, using the solution draw process described below. This can require one to several coats depending on tubing specifications and encapsulating material 74 viscosity. Typically inner layers are coated to thicknesses of 0.0005-0.005 inches. Solution draw rates of 6-18 inches per minute are used to apply the encapsulating material 74.

The solution draw process is comprised of a number of steps. The first step is to prepare the encapsulating material in a solution form. The mandrel 72 is drawn through the solution of the encapsulating material 74. The solution is held in a container and the container contains a hole slightly larger than the size of the mandrel. The mandrel is

then drawn through the solution and the encapsulating material 74 is deposited on the mandrel 72. The resulting encapsulating material thickness is highly controllable due to the propensity of the encapsulating material to adhere to the mandrel 72.

Now referring to Figure 8 which shows a cross sectional diagram of the mandrel 72 and thin coating of encapsulating material 74. After the proper thickness of encapsulating material 74 has been applied, the mandrel and encapsulating material 74 must be cured at room temperature for 6-8 hours. This allows total solvent evaporation.

The process variables for step one (mandrel coating) are summarized as follows in Table E.

15

TABLE E

Environmental	
Ambient temp:	65°F-76°F
Humidity:	10-35% relative
Solution Viscosity:	1- 100 centistokes
20 Solution Draw Rate:	6-18 inches per minute
Solvent Evaporation Rate:	1 4 . 5 u s i n g NButylacetate standard
Solution Temp.	65°F - 76°F
25 Solution Chemistry	6% - 14% solids (Such as Polyurethane in solution with highly polar solvents.)

The coil wrapping process involves wrapping the reinforcing coil wire 54 at the proper tension and pitch. The coil wire is wrapped around the coated mandrel 72 encapsulating material substrate uniformly to the desired specifications. The coil's material composition, rotational speed, tension, substrate diameter and pitch determine the size and flexibility of the coil.

Now referring to Figure 9 which shows the method of constructing the reinforcing coil 54 on the encapsulating material substrate 74. The coil 54 in one embodiment of the invention is wrapped around the
5 mandrel 72.

Now referring to Figure 10 which shows a cross section of a kink resistant tube being constructed from the method of the invention. The coated mandrel substrate 74 is placed and secured in the coil
10 wrapping apparatus 73. The coil wrapping apparatus 73 may be any suitable coil wrapping machine such as, for example, an Accuwinder (TM) machine as manufactured by the Accuwinder Company of California. The coil wire 54 must adhere to the lead end of the mandrel
15 substrate 75 and allowed to cure. The substrate 74 is then wrapped from end to end using the predetermined coil wrapping parameters. Once the coil wrap is complete, the coil 54 must be locked or secured to the coated mandrel substrate 74 using adhesives. This is
20 done at a coil termination 77. After the adhesive has cured, the wire 54 can be cut and the coiled substrate removed from the machinery 73.

The process variables for the coiling operation include the wire wrapping speed and coil wire tension.
25 Experimental trials have determined that the wrapping speed should be between about 500 and 4000 rpm and the coil wire tension should be between about 25 and 200 grams.

Now referring to Figure 11 which shows the method
30 of the invention used to apply an over coating to the coil assembly. The coil 54 is over coated to a predetermined thickness using the solution draw process described above. The process variables used in the solution draw of the encapsulating material are
35 discussed above.

Now referring to Figure 12 which shows the coil

54 assembly over coated to the predetermined thickness. The solution draw process has covered mandrel 72 forming kink resistant tubing 90 with encapsulating material. The surface 26 of the tubing
5 90 is formed by the outside of encapsulating material 22 solidifying around the reinforcing coil 54.

Now referring to Figures 13 and 14 which show the method of the invention used to extract the mandrel 72 from the kink resistant tubing 90. Once the kink
10 resistant tube assembly 90 has been fully cured, the final step is to extract the mandrel 72. This is done by securing each exposed termination of the mandrel 72 and applying sufficient and directionally opposite forces indicated by directional arrows 91 and 93 to
15 plastically reduce the diameter of the mandrel 72 by 10-50%. Once this is accomplished, the mandrel 72 can simply be removed from the tubing assembly.

The invention has been described herein in considerable detail in order to comply with the Patent
20 Statutes and to provide those skilled in the art with the information needed to apply the novel principles and to construct and use such specialized components as are required. However, it is to be understood that the invention can be carried out by specifically
25 different equipment and devices, and that various modifications, both as to the equipment details and operating procedures, can be accomplished without departing from the scope of the invention itself.

What is claimed is:

CLAIMS

1. A kink resistant catheter tube (10) comprising:
 - (a) a thin walled tube (12) having an outside wall (16) and an inside wall (18); and
 - 5 (b) means for reinforcing the thin walled tube (14) wherein the means for reinforcing (14) intimately contacts the outside wall (16).
2. The kink resistant catheter tube (10) of claim 1 further comprising a means for encapsulation (12) intimately contacting the reinforcing means (14).
- 10 3. The kink resistant catheter tube (10) of claim 1 wherein the reinforcing means (14) comprises a wire (34) wound around the thin walled tube (12) in intimate contact with the outside wall (16).
- 15 4. The kink resistant catheter tube (10) of claim 3 wherein the wire (34) is spirally wound around the thin walled tube (22).
5. The kink resistant catheter tube (10) of claim 3 wherein the wire (14) forms rings around the thin walled tube (12).
- 20 6. The kink resistant catheter tube (10) of claim 3 wherein the wire (14) substantially comprises a metal wire.
7. The kink resistant catheter tube (10) of claim 3 wherein the wire (54) is made of a material selected from the group consisting of stainless steel, MP35, NITi, tungsten, platinum, kevalar, nylon, polyester and acrylic.
- 25 8. The kink resistant catheter tube (10) of claim 3 wherein the wire (54) has a cross section and the cross section shape is rectangular.
- 30 9. The kink resistant catheter tube (10) of claim 3 wherein the wire (34) has a cross section and the cross section shape is substantially circular.
- 35 10. The kink resistant catheter tube (10) of claim 1 wherein the thin walled tube (22) is made from a

material selected from the group consisting of polyesterurethane, polyetherurethane, aliphatic polyurethane, polyimide, polyetherimide, polycarbonate, polysiloxane, hydrophilic polyurethane, polyvinyls, latex, and hydroxy-ethyl methacrylate.

11. The kink resistant catheter tube (10) of claim 2 wherein the means for encapsulation (12) is made from a material selected from the group consisting of polyesterurethane, polyetherurethane, aliphatic polyurethane, polyimide, polyetherimide, polycarbonate, polysiloxane, hydrophilic polyurethane, polyvinyls, latex, and hydroxy-ethyl methacrylate.

12. The kink resistant catheter tube (10) of claim 2 wherein the means for encapsulation (12) is an encapsulating thin walled tube (42) surrounding the outside wall.

13. A small diameter kink resistant tube (10) comprising:

- (a) a thin walled tube (74) having an outside wall (75) and inside wall; and
- (b) wire means (54) for reinforcing the thin walled tubular substrate (74) wherein the wire means (54) is wound around the outside wall (75) and intimately contacts the outside wall (75).

14. The small diameter kink resistant catheter tube (90) of claim 13 further comprising a means for encapsulation (22) intimately contacting the reinforcing means (54).

15. The small diameter kink resistant catheter tube (90) of claim 13 wherein the wire (54) is spirally wound around the thin walled tube (74).

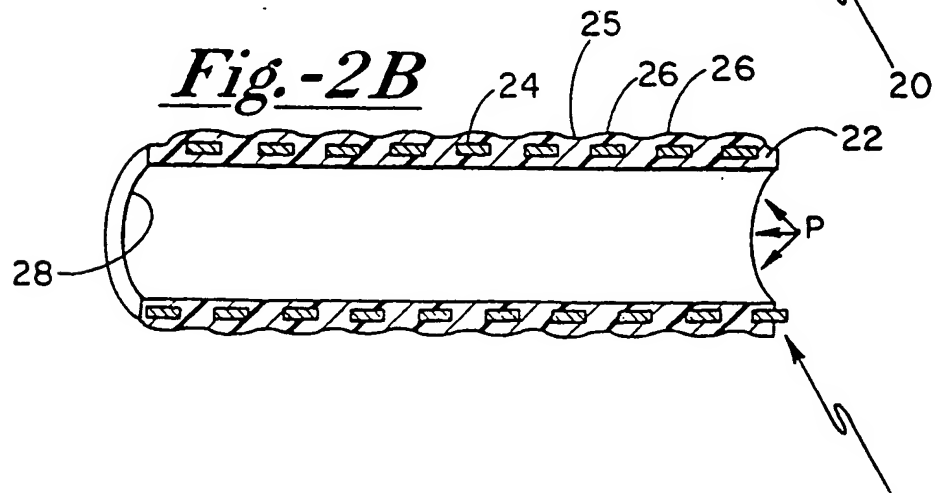
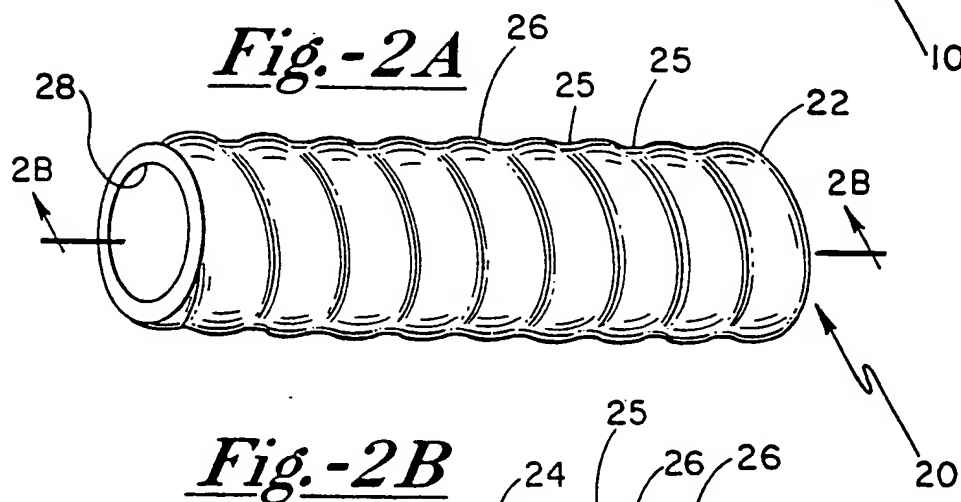
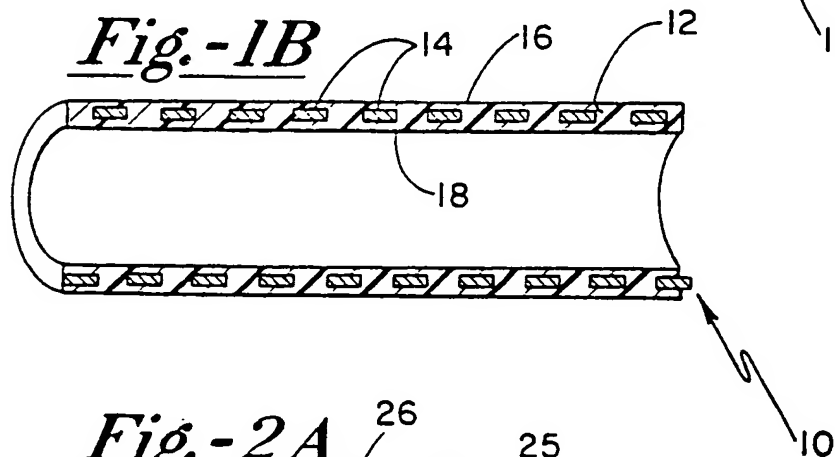
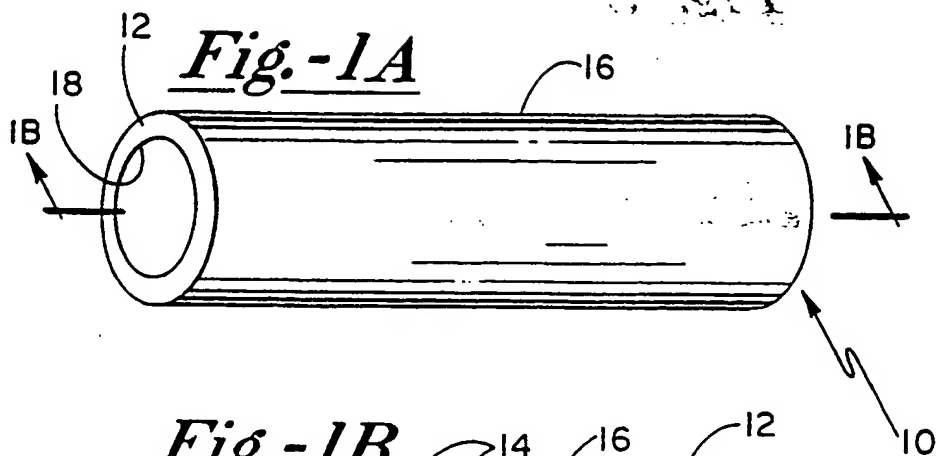
16. The small diameter kink resistant catheter tube

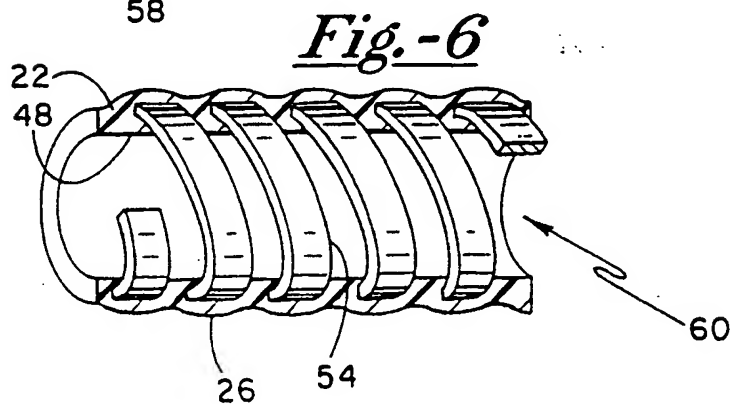
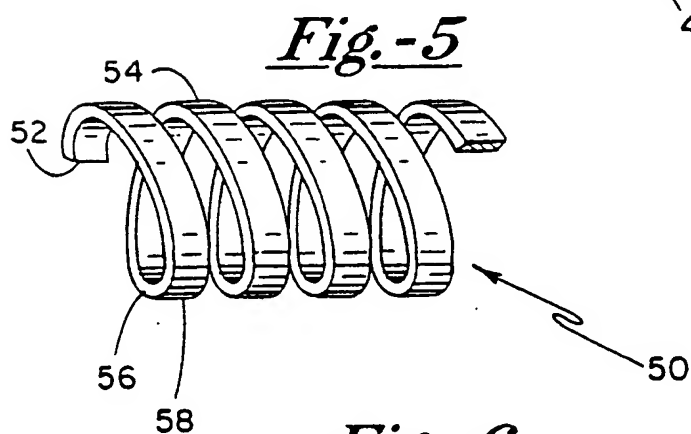
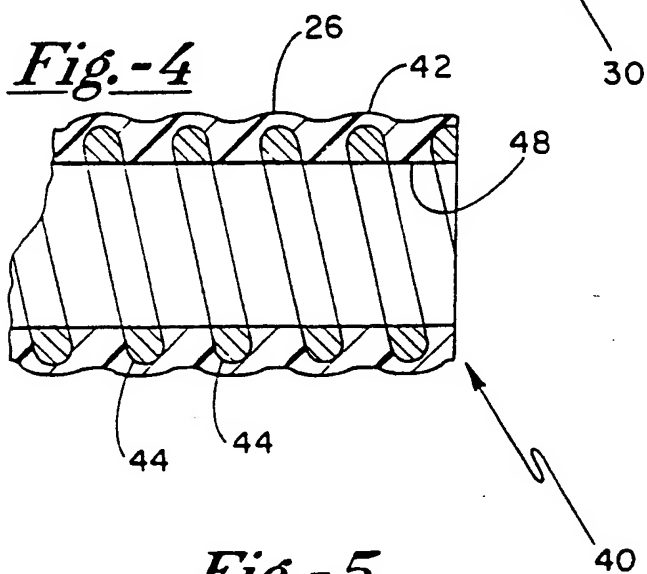
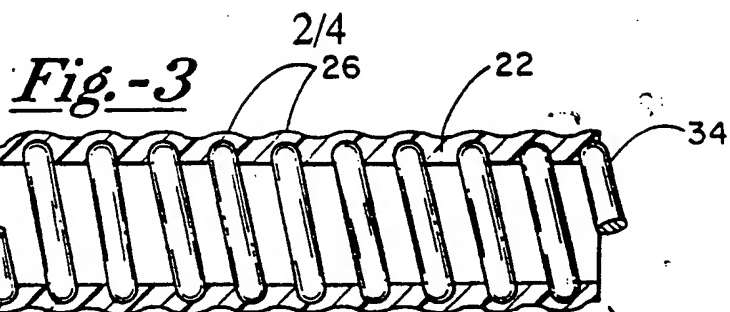
- (90) of claim 13 wherein the wire (54) forms rings around the thin walled tube (74).
17. The small diameter kink resistant tube (90) of claim 13 wherein the wire (54) is a metal wire.
- 5 18. The small diameter kink resistant tube (90) of claim 13 wherein the wire (54) is made of a material selected from the group consisting of stainless steel, MP35, NITi, tungsten, platinum, kevalar, nylon, polyester and acrylic.
- 10 19. The small diameter kink resistant tube (60) of claim 13 wherein the wire (54) has a cross section and the cross section shape is rectangular.
- 15 20. The small diameter kink resistant tube (30) of claim 13 wherein the wire (34) has a cross section and the cross section shape is substantially circular.
- 20 21. The small diameter kink resistant tube (90) of claim 13 wherein the thin walled tube (74) is made from a material selected from the group consisting of polyesterurethane, polyetherurethane, aliphatic polyurethane, polyimide, polyetherimide, polycarbonate, polysiloxane, hydrophilic polyurethane, 25 polyvinyls, latex, and hydroxy-ethyl methacrylate.
- 30 22. The small diameter kink resistant tube (90) of claim 14 wherein the means for encapsulation (22) is made from a material selected from the group consisting of polyesterurethane, polyetherurethane, aliphatic polyurethane, polyimide, polyetherimide, polycarbonate, polysiloxane, hydrophilic polyurethane, polyvinyls, latex, and hydroxy-ethyl 35 methacrylate.
23. The small diameter kink resistant tube (90) of

claim 14 wherein the means for encapsulation (22) is an encapsulating thin walled tube surrounding the outside wall.

- 5 24. The method of claim 3 wherein the wire size ranges from 0.001 inches to 0.015 inches.
25. The method of claim 3 wherein the wire (34) forms a coil and the coil has a pitch ranging from 1 to 5 times the maximum wire dimension.
- 10 26. The method of claim 3 wherein the wire (34) forms a coil and the coil has a diameter from 0.010 inches to 0.375 inches.
27. The method of claim 13 wherein the wire size ranges from 0.001 inches to 0.015 inches.
- 15 28. The method of claim 13 wherein the wire (34) forms a coil and the coil has a pitch ranging from 1 to 5 times the maximum wire dimension.
29. The method of claim 13 wherein the wire (34) forms a coil and the coil has a diameter from 0.010 inches to 0.375 inches.

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Fig.-7

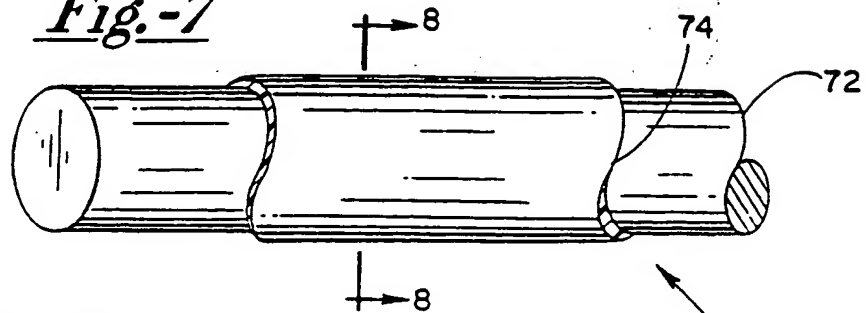


Fig.-8

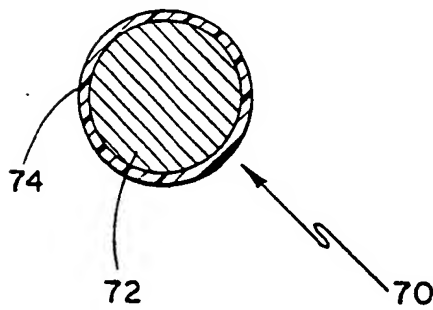


Fig.-9

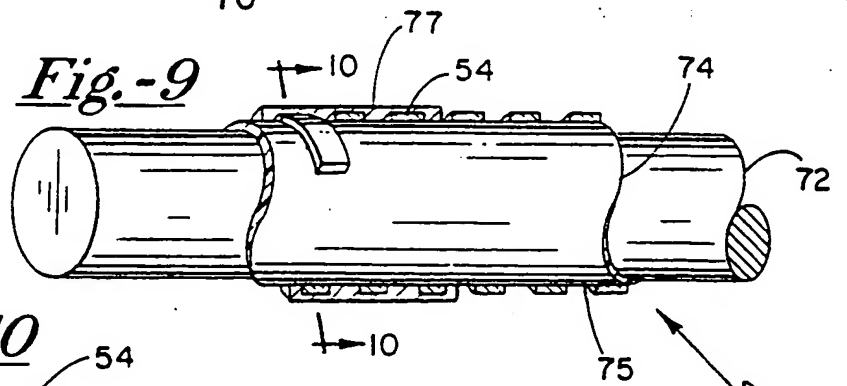
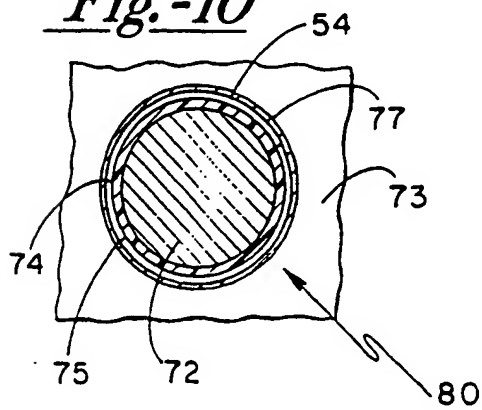


Fig.-10



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Fig.-11

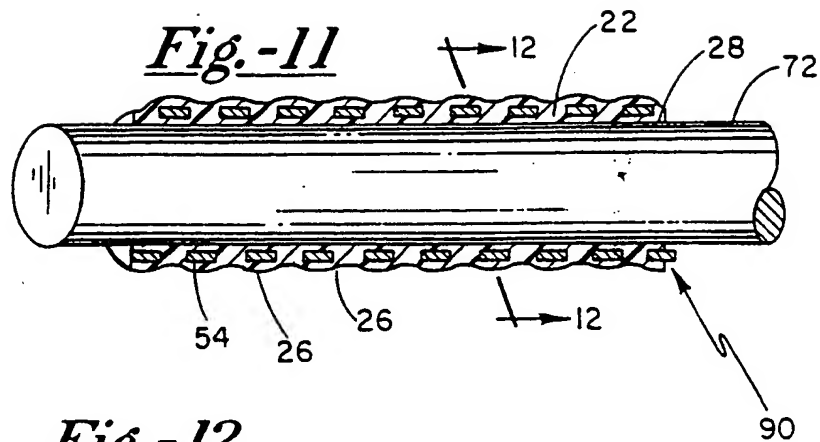


Fig.-12

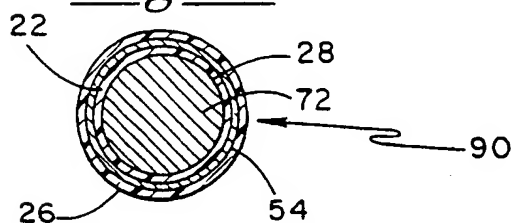


Fig.-13

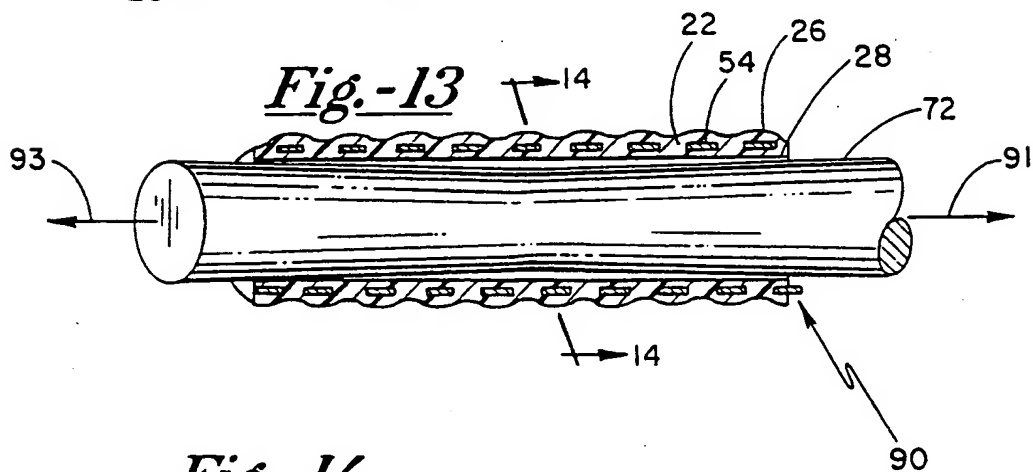
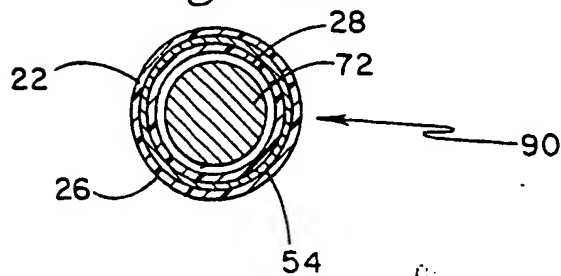


Fig.-14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US93/01323

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :A61M 25/00

US CL :604/282 138/174

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 138/126,125,122,144,150

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
APS- kink resistant, kevalar, polyesterurethane, polyetherurethane

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
<u>X</u> Y	US,A, 4,196,755 (Kutnyak et al.) 08 April 1980 entire reference.	1-6, 9-11, 13- <u>17,20-22</u> 7,8,12,18, 19&23,24-29
Y	US,A, 3,477,474 (Mesler) "11 November 1969" entire reference.	12 & 23
Y	US,A, 4,172,473 (Lefere et al.) 30 October 1979 see col. 3, lines 35-37 & fig. 2.	7,8,18 & 19
A	US,A, 4,817,613 (Jaraczewski et al.) 04 April 1989	1-29
A	US,A, 4,167,953 (Carlstrom) 18 September 1979.	1-29

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be part of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z*	document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means		
P document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 26 MARCH 1993	Date of mailing of the international search report 10 MAY 1993
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US93/01323

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A, 4,892,539 (Koch) 09 January 1990.	1-29
A	US,A, 5,059,375 (Lindsay) 22 October 1991.	1-29
A	US,A, 4,987,182 (Creasy) 22 January 1991.	1-29
A	US,A, 4,847,324 (Creasy) 11 July 1989.	1-29
A	US,A, 3,865,776 (Gergen) 11 February 1975.	1-29
A	US,A, 3,720,235 (Schrock) 13 March 1973.	1-29
A	US,A, 4,140,154 (Kanao) 20 February 1979.	1-29
A	US,A, 4,759,388 (Kiyama et al.) 26 July 1988.	1-29
A,P	US,A, 5,180,376 (Fischell) 19 January 1993.	1-29
A	US,A, 5,001,305 (Bartholomew) 19 May 1991.	1-29
A	US,A, 4,830,694 (Kanao) 16 May 1989.	1-29
A	US,A, 5,072,759 (Moore) 17 December 1991.	1-29